Intracranial arachnoid cysts in a chimpanzee (Pan troglodytes).

AUTHOR(S):

Miyabe-Nishiwaki, Takako; Kaneko, Takaaki; Sakai, Tomoko; Kaneko, Akihisa; Watanabe, Akino; Watanabe, Shohei; Maeda, Norihiko; ... Tomonaga, Masaki; Matsuzawa, Tetsuro; Mikami, Akichika

CITATION:

Miyabe-Nishiwaki, Takako ...[et al]. Intracranial arachnoid cysts in a chimpanzee (Pan troglodytes).. Primates 2013, 55(1): 7-12

ISSUE DATE:

2013-09-26

URL:

http://hdl.handle.net/2433/197658

Intracranial arachnoid cysts in a chimpanzee (*Pan troglodytes*)

Takako Miyabe-Nishiwaki[1], Takaaki Kaneko[1], Tomoko Sakai[1], Akihisa Kaneko[1], Akino Watanabe[1], Shohei Watanabe[1], Norihiko Maeda[1], Kiyonori Kumazaki[1], Juri Suzuki[1,*], Reina Fujiwara[2], Haruyuki Makishima[3], Takeshi Nishimura[1], Misato Hayashi[1], Masaki Tomonaga[1], Tetsuro Matsuzawa[1], Akichika Mikami[4]

[1] Primate Research Institute, Kyoto University, Inuyama, Aichi, Japan

[2] Veterinary Medical Center, The University of Tokyo, Tokyo, Japan

[3] Laboratory of physical anthropology, Kyoto University, Kyoto, Japan

[4] Chubu Gakuin University, Gifu, Japan

Correspondence: Dr. Juri Suzuki

Primate Research Institute, Kyoto University

41-2 Kanrin, Inuyama, Aichi 484-8506, Japan

Tel: +81-568-63-0586 Email: suzuki.juri.4u@kyoto-u.ac.jp (J. Suzuki)

Abstract

An intracranial arachnoid cyst was detected in a 32-year-old, 44.6-kg, female chimpanzee at the Primate Research Institute, Kyoto University. Magnetic resonance imaging (MRI) and computed tomography (CT) were performed and the cognitive studies in which she participated were reviewed. MRI revealed that the cyst was present in the chimpanzee's right occipital convexity, and was located in close proximity to the posterior horn of the right lateral ventricle without ventriculomegaly. CT confirmed the presence of the cyst and no apparent signs indicating previous skull fractures were found. The thickness of the mandible was asymmetrical, whereas the temporomandibular joints and dentition were symmetrical. She showed no abnormalities in various cognitive studies since she was 3 years old, except a different behavioural pattern during a recent study, indicating a possible visual field defect. Detailed cognitive studies, long-term observation of her physical condition and follow-up MRI will be continued.

Key words: ape, primates, brain lesion, MRI, CT, neuroimaging

Introduction

An arachnoid cyst is an accumulation of intra-arachnoid fluid, which can be congenital or secondary to inflammation, brain trauma, haemorrhage, chemical irritation or tumours (Cincu et al. 2007). In humans, most arachnoid cysts are detected during the first two decades of life (Gosalakkal 2002). They are often asymptomatic and are encountered as incidental findings of neuroimaging (Spansdahl and Solheim 2007). Arachnoid cysts can cause headaches, seizures, craniomegaly, developmental delays and, rarely, hemiparesis as well as various defects specific to the location of the cysts. The aetiology of congenital cysts remains unclear, but they are considered to be developmental anomalies of the arachnoid membrane, which resulted in the accumulation of cerebrospinal fluid (CSF)-like fluid. Arachnoid cysts are mainly supratentorial (90%) and are occasionally present in the posterior fossa (10%). The most common supratentorial site is the middle cranial fossa (60%) and other sites include the quadrigeminal plate, sellar region and convexity (Cincu et al. 2007).

Intracranial arachnoid cysts have also been reported in cattle (Lee et al. 2009) and dogs (Vernau et al. 1997; Kitagawa et al. 2003; Dewey et al. 2007; Wyss-Fluehmann et al. 2008), whereas spinal arachnoid cysts are more common in dogs and cats (Skeen et al. 2003). However, arachnoid cysts in non-human primates have rarely been documented. In the present report, we describe magnetic resonance imaging (MRI) and computed tomography (CT) findings in a female chimpanzee with an intracranial arachnoid cyst and briefly review the cognitive studies in which she participated.

Case Report

An intracranial arachnoid cyst was detected in a 32-year-old, 44.6-kg (at the time of

initial MRI), female chimpanzee named Pendesa at the Primate Research Institute, Kyoto University (KUPRI). The chimpanzee was kept in an indoor–outdoor enclosure in a social group comprising 2 males and 4 females: see (Matsuzawa 2003, 2006) for further information concerning the social group.

The chimpanzee was born at the Japan Monkey Centre (JMC) in 1977 and was transferred to KUPRI in 1979 when she was two years old. She participated in various cognitive research studies since then, but has never been used for medical research. All studies after 1986 were conducted under the guidelines provided by the KUPRI after the approval of institutional Animal Welfare and Care Committee. She was diagnosed with atopic dermatitis in 2000, which has been controlled with an oral antihistamine (Salatine, Nipro Genepha Corporation, Saitama, Japan) and topical application of jojoba oil during the dry seasons. No neurological signs were noted before MRI (General Electrics Signa Profile MRI scanner, 0.2 T, GE Yokoo Medical Systems Co., Tokyo, Japan) was performed for research purposes.

Results

The chimpanzee was anesthetized with ketamine hydrochloride (100 mg/mL Ketalar®, 3.5 mg/kg; Sankyo-Parke-Davis & Co., Inc., Japan) and medetomidine hydrochloride (0.035 mg/kg; Domitor®; Meiji Seika Kaisha, Ltd., Tokyo, Japan). Anaesthesia was maintained with isoflurane (Isoflu; Dainippon Sumitomo Pharma Co., Ltd. , Osaka, Japan) delivered in oxygen through a precision vaporizer and a rebreathing circuit. MRI was performed to study the morphology of chimpanzee's brain (Sakai et al. 2011), which revealed an arachnoid cyst in the right occipital convexity (Fig. 1A-C). The cyst was located in close proximity to and possibly communicated with the posterior horn of the right lateral ventricle, but no evidence of ventriculomegaly was

observed. T1- and T2-weighted MRI signals in the cyst were similar to those in CSF. These images were viewed and discussed with both veterinary and human neurologists.

We acquired three-dimensional (3D) T1-weighted whole brain images using the 3D fast gradient echo imaging sequence. The images were analysed using the following series of manual and automated procedures: (i) analyses using Analyze 9.0 software (Mayo Clinic, Rochester, MN, USA) and conversion to cubic voxel dimensions of 0.55 mm using a cubic spline interpolation algorithm, (ii) re-alignment of brain image volumes to a standard anatomical orientation with the transaxial plane parallel to the anterior commissure–posterior commissure line and perpendicular to the interhemispheric fissure, (iii) manual tracing and measurement of the entire arachnoid cyst by one of the image analysts (T.S.) in consultation with a veterinarian (J.S.) and (iv) calculation of the absolute volume of the arachnoid cyst from an automatic count of the number of voxels per cm^3 using Analyze 9.0 software, which resulted in a total volume of 2.8 cm^3.

One year after the initial MRI, the chimpanzee was anesthetized as mentioned above except that sevoflurane (Sevoflo; Dainippon Sumitomo Pharma Co., Ltd. , Osaka, Japan) was used instead of isoflurane and CT was performed using the Asteion CT scanner (model no. TSX-021B; Toshiba Medical Systems Corporation, Tochigi, Japan), which revealed an arachnoid cyst that did not appear to change in size over the preceding one year. The chimpanzee's skull was smooth, and CT did not reveal apparent signs indicating previous skull fractures. However, the thickness of her mandible was asymmetrical, whereas her temporomandibular joints and dentition were symmetrical (Fig. 1D). These images were viewed and discussed with a human dentist.

She has not shown any developmental delays or other behavioural

abnormalities, but researchers and her caretakers have noticed that she frequently rocked back and forth while sitting.

Table 1 lists the cognitive studies in which Pendesa participated since she was 3 years old. She participated in various cognitive tests using visual and auditory modalities, but showed no inferiority to the other chimpanzees in any respect, except in a colour classification task (Matsuno et al. 2004). She performed the colour classification task when she was 23 years old and showed less stable classification compared with a female chimpanzee named Ai (Matsuno et al. 2004, review in Matsuno et al. 2006). Ai and Pendesa were the same age and both reared by human. Although they had similar history, only Ai had learned symbolic colour names through long-term training. In this task, Matsuno and colleagues adopted a “nonlinguistic” test to directly compare colour classification by these two chimpanzees. They were shown 124 test colours and asked to match to 9 standard colours, not to symbols. As a result, Pendesa showed significantly less consistent classifications.

The results of the recent cognitive study (conducted when she was 33 years old) indicate that Pendesa had different behavioural patterns, suggesting a possible defect in her left visual field (Kaneko et al., under review). In this study, the detectability of the small light spot presented on several locations of visual field was measured while monitoring the gaze positions by infra-red remote eye-tracker. As a result, the detectability was close to zero around the bottom-left quadrant of visual field.

Discussion

An arachnoid cyst was detected in the right occipital convexity in a clinically healthy, adult, female chimpanzee during MRI for research purposes. One year later, CT confirmed the presence of the cyst and asymmetrical thickness of the chimpanzee’s

mandible. Although it is difficult to differentiate arachnoid cysts and epidermoid cysts or dermoid cysts (ie., if the content of the cyst was cerebrospinal fluid or something else) without diffusion weighted images, in the present case, arachnoid cyst was the most consistent with our MRI and CT images (shape, size and the location of the cyst), history and symptoms.

In humans, occipital convexity arachnoid cysts are rare, but two case reports have documented symptomatic arachnoid cysts in elderly women (Tucker et al. 2006; Suzuki et al. 2009). The cyst volume slowly increased over time in one case; the cyst was located close to the patient's posterior horn of the right lateral ventricle, which may have been related to the cystic growth (Suzuki et al. 2009). The other woman with a cystic lesion in the right occipital convexity presented with a visual field defect and headache. A visual field examination showed left lower quadrantanopia. Surgical treatment was performed and her headache and visual field defect improved (Suzuki et al. 2009).

In the present case, an arachnoid cyst was located in the right occipital convexity, which was considered to be mostly in V1 area (Bailey et al. 1950). Neither the researchers nor caretakers noticed any developmental delays or other behavioural abnormalities until recently except frequent to-and-fro rocking while sitting. The chimpanzee has participated in various cognitive studies measuring a wide range of visual and auditory functions without any intervals since she was 3 years old. She showed no abnormalities or inferiority in performance and was occasionally even better than other chimpanzees in various tasks, except for the colour classification task (Matsuno et al 2004). Matsuno and colleagues interpreted that Pendesa classified colours less stably because she had less training and limited understanding of colour

159 names. It was unlikely that her colour classification ability was affected by the presence
160 of the arachnoid cyst. More recently, the left visual field defect was suggested in a
161 cognitive study (Kaneko et al, under review). This suspected left quadrantanopia was
162 consistent with a defect that was predicted from the cyst location.

163 Arachnoid cysts can be congenital or secondary to inflammation or brain
164 trauma (Gosalakkal 2002; Cincu et al. 2007). In the present case, a history of brain
165 trauma was not recorded after the chimpanzee was transferred to KUPRI at the age of 2
166 years, although her history before this period was not clear. Apparent signs of previous
167 skull fractures were not found, but CT revealed obvious mandibular asymmetry. The
168 causes of mandibular asymmetry can be developmental, traumatic, pathological (e.g.,
169 tumour, cysts, infection) or functional (mandibular displacement) (Chia et al 2008). In
170 this case, traumatic, pathological and functional causes were not found and it appears to
171 be similar to the developmental condition, hemimandibular hyperplasia in humans (Chia
172 et al 2008). The asymmetry was not obvious from photographs
173 (http://langint.pri.kyoto-u.ac.jp/ai/en/friends/pendesa.html) and it was not clear when
174 the condition developed in her life. Reportedly, patients with congenital arachnoid cysts
175 occasionally have additional malformations (Cincu et al. 2007). Collectively, it is
176 possible that the arachnoid cyst and the mandibular asymmetry were both based on her
177 genetic background. However, if a suspected visual field defect is, in fact, associated
178 with a cyst, it can be contradictory to a congenital cyst because the function is likely to
179 be compensated during development. In such cases, the cyst might have developed at
180 some point after birth and gradually expanded to eventually show symptoms. A
181 histopathological examination can distinguish congenital cysts from secondary cysts
182 because the walls in congenital cysts contain arachnoid cells connected with unchanged

arachnoid matter, whereas those in secondary cysts contain arachnoid scarring (Cincu et al. 2007).

It was difficult to assess whether the chimpanzee had headaches. At least, she did not seem to suffer from headaches to the extent that her social life was impaired. Her frequent rocking behaviour was considered to be a stereotype behaviour and was caused by stress during tasks and/or social influences, despite the enriched environment (Matsuzawa 2003, 2006). However, if she did have a left visual field defect, it could be speculated that she was actually using motion parallax to compensate for her impaired visual field.

We believe that this is the first description of an arachnoid cyst causing possible visual defects in a chimpanzee. Precise behavioural testing on visual fields and blindness is in progress. The general behaviour and physical condition of Pendesa will be continuously observed and follow-up MRI will be performed throughout her lifetime to determine the course of the cyst.

Acknowledgments

We wish to thank Prof. Kozo Matsubayashi at the Center for Southeast Asian Studies, Kyoto University for his assistance in interpreting the MRI images and Dr. W. Saito at Tsurumi University for his assistance in interpreting the CT images. We thank Prof. S. Hirata at Wildlife Research Centre, Kyoto University, Dr. M. Tanaka at Wildlife Research and Education Center, Kyoto City Zoo, and Dr. S. Itakura at Department of Psychology, Kyoto University for valuable information.

This study was financially supported by the following grants: MEXT 16002001, 20002001, 24000001 (to T.M.) and JSPS-gCOE (A06).

207 **References**

208 Anderson JR, Myowa-Yamakoshi M, Matsuzawa T (2004) Contagious yawning in
209 chimpanzees. Proceedings Biological sciences / The Royal Society 271 Suppl
210 6:S468-470. doi:10.1098/rsbl.2004.0224
211 Bailey P, Bonin GV, McCulloch WS (1950) The isocortex of the chimpanzee. University of
212 Illinois Press, Urbana
213 Chia MSY, Naini FB, Gill DS (2008) The aetiology, diagnosis and management of
214 mandibular asymmetry. Orthodontic Update 2008; 1:44-52
215 Cincu R, Agrawal A, Eiras J (2007) Intracranial arachnoid cysts: current concepts and
216 treatment alternatives. Clinical neurology and neurosurgery 109 (10):837-843.
217 doi:10.1016/j.clineuro.2007.07.013
218 Dewey CW, Krotscheck U, Bailey KS, Marino DJ (2007) Craniotomy with cystoperitoneal
219 shunting for treatment of intracranial arachnoid cysts in dogs. Veterinary surgery :
220 VS 36 (5):416-422. doi:10.1111/j.1532-950X.2007.00287.x
221 Gosalakkal JA (2002) Intracranial arachnoid cysts in children: a review of pathogenesis,
222 clinical features, and management. Pediatric neurology 26 (2):93-98
223 Goto K, Imura T, Tomonaga M (2012) Perception of emergent configurations in humans
224 (Homo sapiens) and chimpanzees (Pan troglodytes). Journal of experimental
225 psychology Animal behavior processes 38 (2):125-138. doi:10.1037/a0026899
226 Hirata S, Matsuzawa T (2001) Tactics to obtain a hidden food item in chimpanzee pairs (Pan
227 troglodytes). Animal cognition 4 (3-4):285-295. doi:10.1007/s100710100096
228 Hirata S (2007) A note on the responses of chimpanzees (Pan troglodytes) to live self-images
229 on television monitors. Behavioural processes 75 (1):85-90.
230 doi:10.1016/j.beproc.2007.01.005

231 Huffman MA, Hirata S (2004) An experimental study of leaf swallowing in captive
232 chimpanzees: insights into the origin of a self-medicative behavior and the role of
233 social learning. Primates; journal of primatology 45 (2):113-118.
234 doi:10.1007/s10329-003-0065-5
235 Imura T, Tomonaga M, Yagi A (2008) The effects of linear perspective on relative size
236 discrimination in chimpanzees (Pan troglodytes) and humans (Homo sapiens).
237 Behavioural processes 77 (3):306-312. doi:10.1016/j.beproc.2007.07.006
238 Itakura S, Tanaka M (1998) Use of experimenter-given cues during object-choice tasks by
239 chimpanzees (Pan troglodytes), an orangutan (Pongo pygmaeus), and human infants
240 (Homo sapiens). Journal of comparative psychology 112 (2):119-126
241 Iversen IH, Matsuzawa T (1996) Visually guided drawing in the chimpanzee (Pan
242 troglodytes)1. Japanese Psychological Research 38 (3):126-135.
243 doi:10.1111/j.1468-5884.1996.tb00017.x
244 Iversen IH, Matsuzawa T (1997) Model-guided Line Drawing in the Chimpanzee (Pan
245 troglodytes). Japanese Psychological Research 39 (3):154-181.
246 doi:10.1111/1468-5884.00051
247 Iversen IH, Matsuzawa T (2003) Development of interception of moving targets by
248 chimpanzees (Pan troglodytes) in an automated task. Animal cognition 6 (3):169-183.
249 doi:10.1007/s10071-003-0175-x
250 Kaneko T, Tomonaga M (2011) The perception of self-agency in chimpanzees (Pan
251 troglodytes). Proceedings Biological sciences / The Royal Society 278
252 (1725):3694-3702. doi:10.1098/rspb.2011.0611
253 Kaneko T, Tomonaga M (2012) Relative contributions of goal representation and kinematic
254 information to self-monitoring by chimpanzees and humans. Cognition 125

(2):168-178. doi:10.1016/j.cognition.2012.07.006

Kitagawa M, Kanayama K, Sakai T (2003) Quadrigeminal cisterna arachnoid cyst diagnosed by MRI in five dogs. Australian veterinary journal 81 (6):340-343

Kojima S, Kiritani S (1989) Vocal-auditory functions in the chimpanzee: Vowel perception. Int J Primatol 10 (3):199-213. doi:10.1007/BF02735200

Kojima S, Tatsumi IF, Kiritani S, Hirose H (1989) Vocal-auditory functions of the chimpanzee: consonant perception. Hum Evol 4 (5):403-416. doi:10.1007/BF02436436

Kojima S (1990) Comparison of auditory functions in the chimpanzee and human. Folia primatologica; international journal of primatology 55 (2):62-72

Lee K, Yamada K, Tsuneda R, Kishimoto M, Shimizu J, Kobayashi Y, Furuoka H, Matsui T, Sasaki N, Ishii M, Inokuma H, Iwasaki T, Miyake Y (2009) Clinical experience of using multidetector-row CT for the diagnosis of disorders in cattle. The Veterinary record 165 (19):559-562

Matsuno T, Kawai N, Matsuzawa T (2004) Color classification by chimpanzees (Pan troglodytes) in a matching-to-sample task. Behavioural brain research 148 (1-2):157-165

Matsuno T, Kawai N, Matsuzawa T (2006) Color Recognition in Chimpanzees (Pan troglodytes) In: Matsuzawa T (ed) Cognitive Development in Chimpanzees. . Springer-Verlag, Tokyo, Japan, pp 317-329

Matsuno T, Tomonaga M (2006) Visual search for moving and stationary items in chimpanzees (Pan troglodytes) and humans (Homo sapiens). Behavioural brain research 172 (2):219-232. doi:10.1016/j.bbr.2006.05.004

Matsuno T, Tomonaga M (2007) An advantage for concavities in shape perception by

279 chimpanzees (Pan troglodytes). Behavioural processes 75 (3):253-258.
280 doi:10.1016/j.beproc.2007.02.028
281 Matsuno T, Tomonaga M (2008) Temporal characteristics of visibility in chimpanzees (Pan
282 troglodytes) and humans (Homo sapiens) assessed by a visual-masking paradigm.
283 Perception 37 (8):1258-1268
284 Matsuzawa T (2003) The Ai project: historical and ecological contexts. Animal cognition 6
285 (4):199-211. doi:10.1007/s10071-003-0199-2
286 Matsuzawa T (2006) Sociocognitive development in chimpanzees: a synthesis of laboratory
287 work and field work. I. In: Matsuzawa T (ed) Cognitive Development in
288 Chimpanzees. . Springer-Verlag, Tokyo, Japan, pp 3-33
289 Sakai T, Mikami A, Tomonaga M, Matsui M, Suzuki J, Hamada Y, Tanaka M,
290 Miyabe-Nishiwaki T, Makishima H, Nakatsukasa M, Matsuzawa T (2011)
291 Differential prefrontal white matter development in chimpanzees and humans.
292 Current biology : CB 21 (16):1397-1402. doi:10.1016/j.cub.2011.07.019
293 Skeen TM, Olby NJ, Munana KR, Sharp NJ (2003) Spinal arachnoid cysts in 17 dogs.
294 Journal of the American Animal Hospital Association 39 (3):271-282
295 Sousa C, Matsuzawa T (2001) The use of tokens as rewards and tools by chimpanzees (Pan
296 troglodytes). Animal cognition 4 (3-4):213-221. doi:10.1007/s100710100104
297 Spansdahl T, Solheim O (2007) Quality of life in adult patients with primary intracranial
298 arachnoid cysts. Acta neurochirurgica 149 (10):1025-1032; discussion 1032.
299 doi:10.1007/s00701-007-1272-4
300 Suzuki M, Tamaki T, Toda S, Tsuchiya M, Kogure K, Hosone M, Node Y, Teramoto A (2009)
301 Delayed recurrent arachnoid cyst of the occipital convexity in an elderly woman.
302 Neurologia medico-chirurgica 49 (3):134-137

303 Tanaka M (2003) Visual preference by chimpanzees (Pan troglodytes) for photos of primates
304 measured by a free choice-order task: implication for influence of social experience.
305 Primates; journal of primatology 44 (2):157-165. doi:10.1007/s10329-002-0022-8
306 Tomonaga M (2007) Is chimpanzee (Pan troglodytes) spatial attention reflexively triggered
307 by gaze cue? Journal of comparative psychology 121 (2):156-170.
308 doi:10.1037/0735-7036.121.2.156
309 Tomonaga M (2008) Relative numerosity discrimination by chimpanzees (Pan troglodytes):
310 evidence for approximate numerical representations. Animal cognition 11 (1):43-57.
311 doi:10.1007/s10071-007-0089-0
312 Tomonaga M, Imura T (2009) Faces capture the visuospatial attention of chimpanzees (Pan
313 troglodytes): evidence from a cueing experiment. Frontiers in zoology 6:14.
314 doi:10.1186/1742-9994-6-14
315 Tomonaga M, Imura T (2010) Pacman in the sky with shadows: the effect of cast shadows on
316 the perceptual completion of occluded figures by chimpanzees and humans.
317 Behavioral and brain functions : BBF 6:38. doi:10.1186/1744-9081-6-38
318 Tucker A, Miyake H, Omura T, Tsuji M, Ukita T, Nishihara K, Oi S (2006) Huge arachnoid
319 cyst of the occipital cerebral convexity. Neurologia medico-chirurgica 46 (7):361-365
320 Ushitani T, Imura T, Tomonaga M (2010) Object-based attention in chimpanzees (Pan
321 troglodytes). Vision research 50 (6):577-584. doi:10.1016/j.visres.2010.01.003
322 Vernau KM, Kortz GD, Koblik PD, LeCouteur RA, Bailey CS, Pedroia V (1997) Magnetic
323 resonance imaging and computed tomography characteristics of intracranial
324 intra-arachnoid cysts in 6 dogs. Veterinary radiology & ultrasound : the official
325 journal of the American College of Veterinary Radiology and the International
326 Veterinary Radiology Association 38 (3):171-176

327 Wyss-Fluehmann G, Konar M, Jaggy A, Vandevelde M, Oevermann A (2008) Cerebellar
328 ependymal cyst in a dog. Veterinary pathology 45 (6):910-913.
329 doi:10.1354/vp.45-6-910
330 Yamamoto S, Humle T, Tanaka M (2009) Chimpanzees help each other upon request. PloS
331 one 4 (10):e7416. doi:10.1371/journal.pone.0007416
332 Yamamoto S, Tanaka M (2009) Do chimpanzees (Pan troglodytes) spontaneously take turns
333 in a reciprocal cooperation task? Journal of comparative psychology 123 (3):242-249.
334 doi:10.1037/a0015838

Table 1. Cognitive studies in which Pendesa participated.

* The age of the chimpanzee at which she participated the task. (-) indicates that the age is not stated in the article.

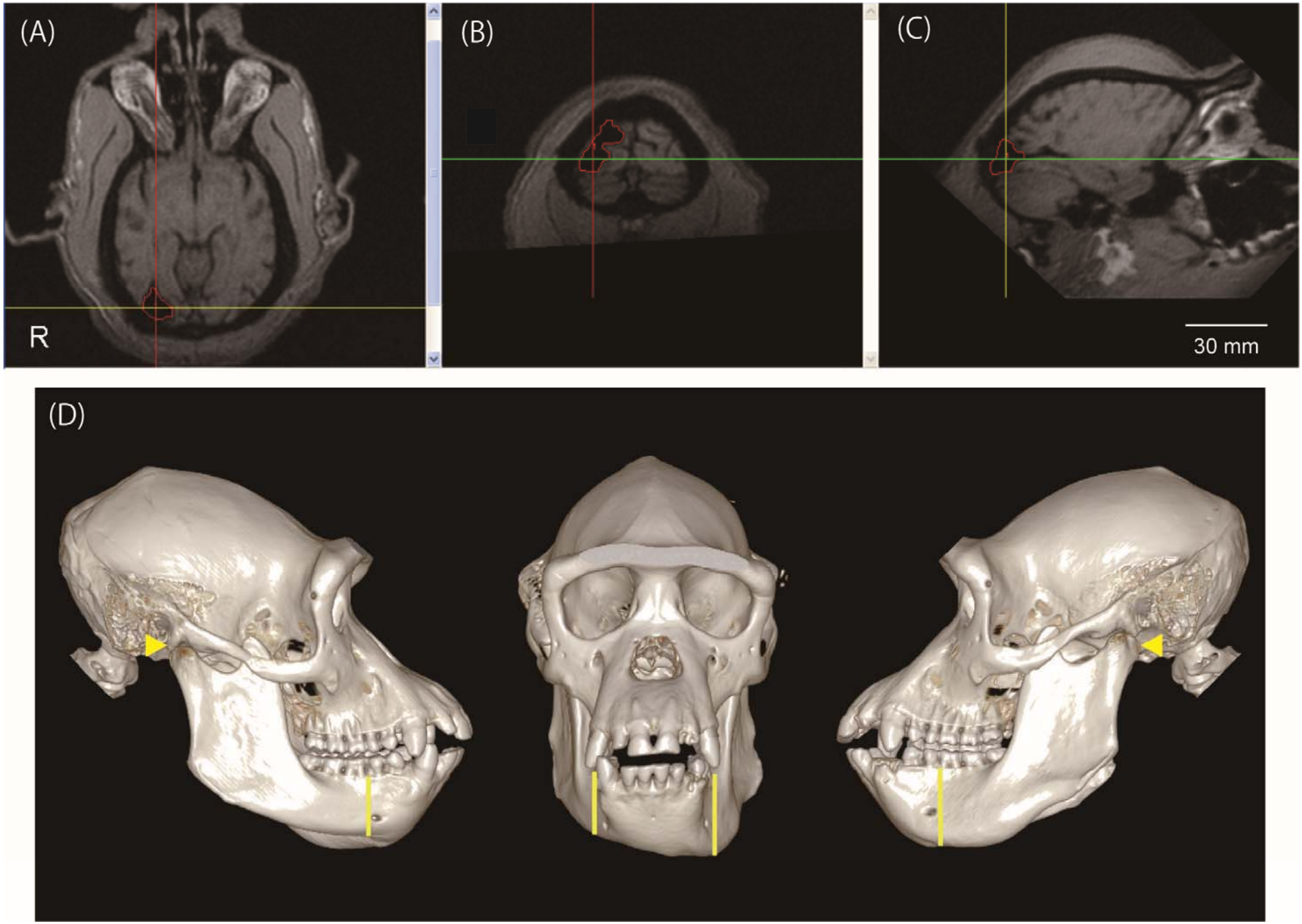
Task category	Task	Topic	Age*	Number of subjects	Reference
Vision	Concurrent discrimination	Self-monitoring of action	-	6	Kaneko and Tomonaga 2012
Vision	Odd item search	Emergent feature	29	3	Goto et al. 2012
Vision	Concurrent discrimination	Agency judgment	-	3	Kaneko and Tomonaga 2011
Vision	Odd item search	Perceptual completion	-	6	Tomonaga and Imura 2010
Vision	Pre-cue task	Object based attention	-	2	Ushitani et al. 2010
Vision	Pre-cue task	Cueing effect of human pointing	-	2	Tomonaga and Imura 2009
Social	Token insertion task	Reciprocal cooperation	29	4	Yamamoto and Tanaka 2009
Social	Tool transfer task	Helping behaviour	-	9	Yamamoto et al. 2009
Vision	Matching to sample	Metacontrast and back/forward masking	28	2	Matsuno and Tomonaga 2008
Vision	Concurrent discrimination	Relative numerosity discrimination	-	2	Tomonaga 2008
Vision	Concurrent discrimination	Pictorial depth cue perception	24	3	Imura et al. 2008
Vision	Matching to sample	Dominant perception of concave shape	28	5	Matsuno and Tomonaga 2007
Vision	Pre-cue task	Gaze cueing effect	-	2	Tomonaga 2007
Social	Free viewing	Mirror self-recognition	21	10	Hirata 2007
Vision	Odd item search	Grouping of moving/stationary object	27	3	Matsuno and Tomonaga 2006
Vision	Matching to sample	Color classification	23	2	Matsuno et al. 2004
Social	Free viewing	Contagious yawning	26	6	Anderson et al. 2004
Ecology	Leaf swallowing	Self-medicative behavior	-	11	Huffman and Hirata 2004
Motor	Hand drawing	Improvement of manual movement	15	2	Iversen and Matsuzawa 2003
Vision	Free choice task	Visual preference of photo	23	5	Tanaka 2003
Social	Open field food detection	Tactical Deception	20	5	Hirata and Matsuzawa 2001
Social	Toke exchange task	Use of token	-	3	Sousa and Matsuzawa 2001
Vision	Object choice task	Recognition of human-given cue	18	2	Itakura and Tanaka 1998
Motor	Hand drawing	Model guided hand drawing	15	2	Iversen and Matsuzawa 1997
Motor	Hand drawing	Visually guided hand drawing	15	2	Iversen and Matsuzawa 1996
Auditory	Go/NoGo	Auditory function	7	2	Kojima 1990
Auditory	Go/NoGo	Consonant perception	9	2	Kojima et al. 1989
Auditory	Go/NoGo	Vowel perception	9	3	Kojima and Kiritani 1989

Figure legends

Fig. 1

T1-weighted coronal (A), axial (B) and sagittal (C) MRI showing a right occipital arachnoid cyst with a total volume of 2.8 cm^3 (contoured area)

(D) 3D reconstructed CT images of the skull. The thickness of the mandible was asymmetrical (yellow bar), whereas the temporomandibular joints (arrowhead) and dentition were symmetrical.


(A)
R
(B)
(C)
30 mm
(D)